

# Future Development and Features of Pumped Storage Stations in China

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**Abstract.** In order to solve the problem of power system peak load regulation and ensure the operation system safe and stable, the current pumped storage power station is still the most effective and economical means. This paper analyzes the development status of pumped storage station, and according to the present operation situation of the pumped storage station in our country, the regional differences in social and economic development and power grid structure, the paper analyzes the functional orientation of the pumped storage station, which can be divided into security, load power supply, help nuclear and new energies absorption. According to our country's actual situation of pumped storage power station of the regional power grid, this paper analyzes the present situation and future trends of function orientation.

## 1.INTRODUCTION

With the rapid development of China's economy, the power load will grow more, and the peak-to-valley difference will increase. At the same time, due to the imbalance of energy resources and power consumption distribution and the adjustment of energy structure and the change of climate, the scale of cross-regional power allocation will be further expanded, and the construction scale of clean energy such as nuclear power, wind power and photovoltaic power generation will increase rapidly. Higher requirements are placed on the safe and reliable operation of the power system. In the case that oil, natural gas, etc. are limited by resource conditions, and new energy storage technologies such as chemical energy storage have not yet achieved a critical breakthrough, pumped storage power stations have functions such as peak shaving, valley filling, the reserve of accident, and the consumption of new energy. It will still play an important role in the power system.

## 2.Development status of pumped storage power stations in China

In 2020, the installed capacity of wind power in Chian will reach 210 million kilowatts, and solar power will reach more than 110 million kilowatts <sup>[1]</sup>. The large-scale development of wind power and solar power has brought new challenges to the peak shaving and safe operation of power systems. As a special power source, pumped storage power station has many functions such as peak load regulation, frequency regulation, accident standby, black start, etc., which plays an important role in ensuring the safe and stable operation of the power system. Its fast response speed and wide adjustment range make it a good power supply for peak load regulation for the system and the most mature energy storage device. Therefore, accelerating the development and rational use of pumped storage power stations will safeguard the safe and stable economic operation of China's power system, alleviate the contradiction of power grid peak shaving, promote energy structure adjustment, increase the consumption of new energy power, promote the development and utilization of clean energy, and



reduce greenhouse gas emissions. It is of great significance to achieve sustainable economic and social development.

In recent years, China's pumped storage installed capacity has been among the highest in the world. Currently, installed capacity accounts for 39.6% of the total pumped storage capacity in Asia and 16.7% of the total pumped storage capacity in the world. In 2016, with the operation of Xianju Pumped Storage, Hongping Pumped Storage and Qingyuan Pumped Storage, the number of pumped storage power stations in the country has reached 28, distributed in 17 provinces and cities, with an installed capacity of 26.69 million kilowatts. The statistics of installed capacities of pumped storage stations is shown in Table 1.

As of the end of 2016, the capacity of pumped storage power stations under construction nationwide totalled 23.76 million kilowatts, as shown in Table 2. The power stations under construction are mainly distributed in East China Power Grid and North China Power Grid, and the Southern Power Grid is the second place. Although the northeast power grid has been deteriorating due to the rapid development of wind power and other reasons, the scale of pumped storage power plants in operation and under construction in the region is still relatively small, and there is no pumped storage in the northwest power grid.

### **3.FUNCTIONAL CLASSIFICATION AND STANDARD OF PUMPED STORAGE POWER STATION**

Pumped storage power stations have many functions, but due to the differences in power supply structure, load characteristics, power supply and demand conditions and power security requirements, the actual role of different power grid pumped storage power stations should be different.

#### *3.1 Functional positioning classification*

The object of pumped storage service is the whole power system. The power grid is the only carrier for pumping and storage. Therefore, the function positioning of pumped storage should be combined with the characteristics of the power grid and keeping up with the times to achieve the goal of effectively guide the construction and operation of pumped storage in various regions. From the current power development situation in China, the functional requirements of the power system for pumped storage are basically concentrated in the above three situations, namely, safety guarantee, peak-shaving and valley-filling, nuclear power and new energy consumption<sup>[3]</sup>.

##### *(1) Security protection*

The safety guarantee function refers to the emergency standby, black start, frequency regulation and phase regulation of the pumped storage unit, which can cope with various emergencies in the power system. These power plants are mainly distributed in important economic and political centres with extremely high power reliability requirements, or key hubs of power grids, such as the UHV DC receiving area, to support the receiving end frequency and active power regulation.

##### *(2) Peak-shaving and valley-filling*

When pumped storage power stations replace conventional thermal power units to solve the problem of peak-shaving and valley-filling, there are economic and technical advantages. First, pumped storage power stations not only have significant peak-cutting performance, but also have unique filling functions. On the basis of meeting the power, power and peak load regulation requirements of the power system to the same extent, the commissioning of pumped storage power stations can reduce the operation of small capacity and high coal consumption units at peak times, and make the thermal power units operate in a more economical position during the trough, saving the total system coal consumption<sup>[4]</sup>, the second is that conventional units often face technical difficulties in sharp peak load regulation, and have to shut down and restart the unit frequently. Pumped storage can effectively alleviate this situation.

##### *(3) Cooperate with nuclear power and new energy consumption*

This type of pumped-storage power station provides directional operational services to match a particular power supply operation. For new energy sources such as wind energy and solar energy,

because of their natural randomness and intermittent characteristics, the effective capacity is low, and the pumped storage power station with a certain capacity can effectively increase the proportion of consumption; nuclear power has extremely high safety operation requirements. It should also be equipped with pumping and storage units of appropriate capacity to provide peak load regulation, energy storage or safety protection, otherwise the design function cannot be fully utilized. It can be said that the pumped storage power station of the directional service type is a necessary "affiliated power station" for wind energy, solar energy and nuclear power.

### 3.2 Functional positioning classification standard

The classification standards of pumped storage power stations in the area where the power station is located are based on the load characteristics, power supply structure, conditions of power from other district, new energy consumption, and nuclear power plant construction, including:

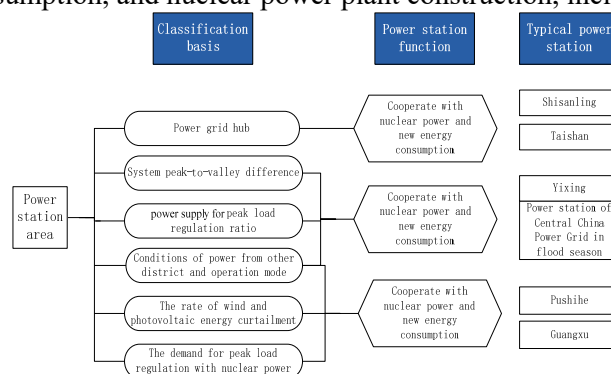


Fig.1 Classification standard of functional orientation of pumped storage stations

(1) Power grid hub: One is that the area where the power station is located or the reliability of power supply is extremely high. For example, near the political and economic centers such as Beijing and Shanghai, the power station function should be positioned as a security guarantee; in addition, when holding large-scale sports events, important international conferences, etc., pumping the power station should also be mainly used as a security guarantee. The other is the key hub node of the regional power grid, such as the large-scale UHV DC drop point area, lack of frequency adjustment and active power support means, and the pumped storage power station should be mainly used as a security guarantee.

(2) System peak-to-valley difference and power supply for peak load regulation ratio: When the peak-to-valley difference of the system load is large in the area where the power station is located, and the proportion of the flexible power supply in the existing power supply structure is low, it is difficult to meet the peak load regulation demand of the system, and the power station function should be positioned as the peak-shaving and valley-filling.

(3) Conditions of power from other district and operation mode: When the proportion of power from other district is high, combined with different power from other district operation modes, the system may have different peaking difficulties. At this time, the function of the internal pumped storage power station should be positioned as a peak-shaving and valley-filling or the service for power from other district.

(4) The rate of wind and photovoltaic energy curtailment: When the new energy consumption in the area where the power station is located is large, and the light-curtailment rate is high due to the peak-shaving capacity, the power station function should be positioned as a service for new energy consumption.

(5) The demand for peak load regulation with nuclear power: When there is a nuclear power plant in the area, and the peak load regulation and safety requirements are met, the power station function should be positioned as the service for nuclear power.

## **4.FUNCTIONAL LOCATION OF PUMPED STORAGE POWER STATIONS IN VARIOUS REGIONAL POWER GRIDS IN CHINA**

### *4.1 North China Power Grid*

At present, the location of pumped storage power stations in the North China Power Grid is mainly based on peak-shaving and valley-filling and security. North China Power Grid is a power grid based on thermal power. At the end of 2016, thermal power installed capacity accounted for 64%. The typical daily peak-to-valley difference of North China Power Grid is about 27% in summer and winter. The heating units in winter use more, but the ability of peak load regulation is only 10%-20% during heating period. Although the proportion of gas units in Beijing-Tianjin-Tangshan area is large, it is basically a gas-fired cogeneration unit, and its adjustment capability is also very limited.

In the future, with the expansion of the power flow and the construction of new energy bases, the newly built pumped storage power stations in the region should focus on the new energy consumption and ensure the safe operation of the receiving power grid. During the “Thirteenth Five-Year Plan” period, with the construction of large wind power bases in Hebei and Inner Mongolia, and the launch of UHV DC projects such as Zharuut-Qingzhou and Shanghai Temple-Linyi, more than 20 million kilowatts of wind power installed capacity and 40 million kilowatts from other district will be added in North China. So the construction of the pumped-storage power station should cope with the consumption of new energy and ensure the safe operation of the power grid.

### *4.2 East China Power Grid*

The pumped storage power stations in the East China Power Grid is mainly based on peak-shaving and valley-filling. The total load of East China Power Grid is large, and the thermal power installed capacity is the main area. The installed capacity of coal power accounts for 65%, and the nuclear power accounts for 5%. The peak-to-valley difference during the summer peak period is more than 30 million kilowatts. The peaking pressure is large, and several pumping energy storage power station in the area has played a huge role in peak-shaving and valley-filling.

In the future, East China Power Grid faces the problems of expanding the scale of power flow and increasing the proportion of nuclear power. Pumped storage power stations should simultaneously play an important role in flexible support power supply and peak-shaving and valley-filling. In the future, the proportion of power input to East China Power Grid will gradually increase. It is expected to reach more than 20% in 2020, and the transmission capacity of the channel will be large. The single-height U-HVDC transmission capacity will reach 10 million kilowatts, and the transition period will form a strong DC and weak AC grid pattern. The pumped-storage power station in the district will become an important power source for the support of the terminal, and the positioning will be gradually changed from peak-shaving and valley-filling to peak-shaving and valley-filling and security.

### *4.3 Central China Power Grid*

At present, the function of pumped storage power stations in Central China Power Grid is mainly based on peaking and valley filling in flood season. Central China Power Grid is China's largest hydropower installed capacity and highest proportion of power grids. In 2016, hydropower installed capacity was 130 million kilowatts, accounting for 44%. In the past, there has been much controversy in the construction of pumped storage power stations in power grids with a high proportion of hydropower. Research and practice show that the proper development of pumped-storage power stations with large-scale of runoff hydropower has the comprehensive benefits of improving the operating conditions of thermal power units, reducing the operating costs of the whole network, and rationally utilizing the seasonal energy of hydropower. For example, Hubei, Hunan, and Henan have different proportions of hydropower, but the proportion of hydropower stations with annual adjustment and above capacity is small. During the dry season, hydropower can be used for peak shaving. In flood season, hydropower will lose its ability to adjust. If hydropower peaking is to be used, only Forced to adopt a method of abandoning water to peak. In such a power grid, after equipped

with a pumped-storage power station, it can absorb the base-loaded electricity in the flood season and convert it into peak-loaded electricity, thereby reducing or avoiding flooding in flood season, improving economic efficiency and improving the operation of hydropower during flood season, and greatly improving the operating conditions of the grid.

In the future, the Central China Pumped Storage Power Station is mainly positioned at the receiving end to support the power supply to ensure safe and stable operation of the power grid. During the “Thirteenth Five-Year Plan” period, the newly-increased power flow in Central China was 38 million kilowatts. With the completion of DC projects such as Jiuquan-Xiangtan and Shanbei-Wuhan, the proportion of power shortage provinces getting power in central China will rise to about 18%, and some channels will be mainly used to transport and distribute power. They have an ability of anti-peaking. The pumped storage power station in the area will shoulder the task of peak-supporting power supply and power grid peaking.

#### *4.4 Northeast Power Grid*

At present, the pumped storage power stations in the Northeast Power Grid is mainly to consumptive the new energy. The Northeast Power Grid is similar to the North China and East China Power Grids. At the end of 2015, the installed capacity of the northeast power supply (120 million kilowatts) has nearly doubled the maximum load (72 million kilowatts), including wind power 24.6 million. , accounting for 34% of the maximum load. Thermal power is mainly based on heating units. In winter, there is basically no capacity of peak load regulation, and there is a huge pressure in the high-speed wind power period about peak load regulation. Therefore, the pumped-storage power stations in this region should be based on the coordination of new energy consumption and relief the difficulty of peak load regulation of power grids<sup>[5]</sup>.

In the future, the newly-built pumped-storage power station of the Northeast Power Grid will still be mainly equipped with new energy consumption. With the completion of the 10 million-kilowatt-class wind power bases in eastern Inner Mongolia and Jilin, Heilongjiang, etc., the Northeast Power Grid will face greater pressure on new energy consumption, and the district should speed up the construction of new pumped storage power stations to alleviate the current serious situation of wind curtailment.

#### *4.5 Northwest Power Grid*

At present, there is no pumped-storage power station in the Northwest Power Grid area, and the planned pumped-storage power station should be positioned to cope with new energy consumption. At the same time, the heavy industry in Gansu, Qinghai, Ningxia and other provinces is more important, and the peak-to-valley difference of the Northwest Power Grid is only about 20%. The past peak load regulation of the Northwest Power Grid has been consistently good. However, with the rapid development of new energy sources such as Gansu, Xinjiang wind power and Qinghai solar power generation in recent years, some regions have weak network and insufficient capacity of peak load regulation. According to relevant plans, by 2020, the installed capacity of wind power in the Northwest Power Grid will reach nearly 50 million, accounting for about 35% of the maximum load. The peak load regulation of the Northwest Power Grid will become increasingly tense. At present, in Gansu, Xinjiang and other places, there have been restrictions on wind power consumption due to insufficient capacity of peak load regulation. In the future, more grid-connected wind power and solar power need higher capacity of peak load regulation. The construction of pumped storage power stations in these areas has become very necessary.

### **5.CONCLUSION**

At present, China's pumped storage operation lacks scientific and reasonable guiding principles, which leads to the difference between the utilization of pumped storage and actual demand, which is largely due to the lack of understanding of the location of pumped storage functions in different regions. Combined with the characteristics of different power grids, the functional positioning of pumped

storage power stations is mainly divided into three categories: safety assurance, peaking power supply, nuclear power and new energy consumption. And this paper gives differentiated functional positioning of power grids in different regions. In the future, the pumped storage power stations in North China and East China Power Grids should be based on accident reserve and peak load regulation in UHV terminal areas; the pumped storage power stations in Central China Power Grid area should be based on the accident reserve for the UHV terminal areas; the pumped storage power station in the northeast, northwest and south power grid areas should be coordinated with the new energy operation and peak load regulation. Reasonable distinction between the functional positioning of pumped storage power stations in different regions is of great significance for guiding the operation of power stations, ensuring the safe and stable economy of China's power system and achieving sustainable economic and social development.

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